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A Small-Scale Safety Test for Initiation Components

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A Small-scale Safety Test for Initiation Components*

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Introduction

We have developed a small-scale safety test for initiation train components. A low-cost test was needed to assess the response of initiation components to an abnormal shock environment and to detect changes in the sensitivity of initiation components as they age. The test uses a disk of Detasheet[1] to transmit a shock through a PMMA barrier into a the test article. A schematic drawing of the fixture is shown in Fig. 1. The 10-cm-diameter disk of 3-mm-thick Detasheet, initiated at its center by a RISI, RP-[2] detonator, produces a shock wave that is attenuated by a variable-thickness PMMA spacer (gap). Layers of metal and plastic above the test article and the material surrounding the test article may be chosen to mock up the environment of the test article at its location in a warhead. A metal plate at the bottom serves as a witness plate to record whether or not the test article detonated. For articles containing a small amount of explosive, it can be difficult to determine whether or not a detonation has occurred. In such cases, one can use a pressure transducer or laser velocimeter to detect the shock wave from the detonation of the article. The assembly is contained in a 10-cm-ID section of PVC pipe and fired in a containment vessel rated at 100 g. Test results are given for a hemispherical, exploding-bridgewire (EBW) detonator.

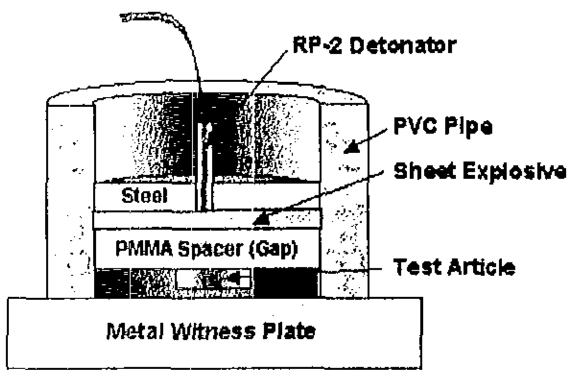

Figure 1. Schematic diagram of the 10-cm test fixture.

Experimental System

We tested the concept of using sheet explosive in a gap test by measuring the attenuation of shock waves produced in a PMMA barrier by detonating Detasheet. We used a test fixture that was developed for small-scale performance tests on high explosives. A photo and drawing of the fixture are shown in Fig. 2.

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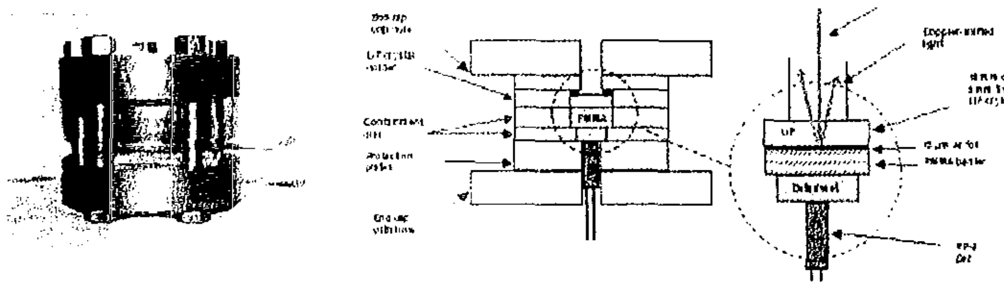

Figure 2. Drawing and photo of the small-scale test fixture used to measure the shock wave transmitted through a PMMA barrier.

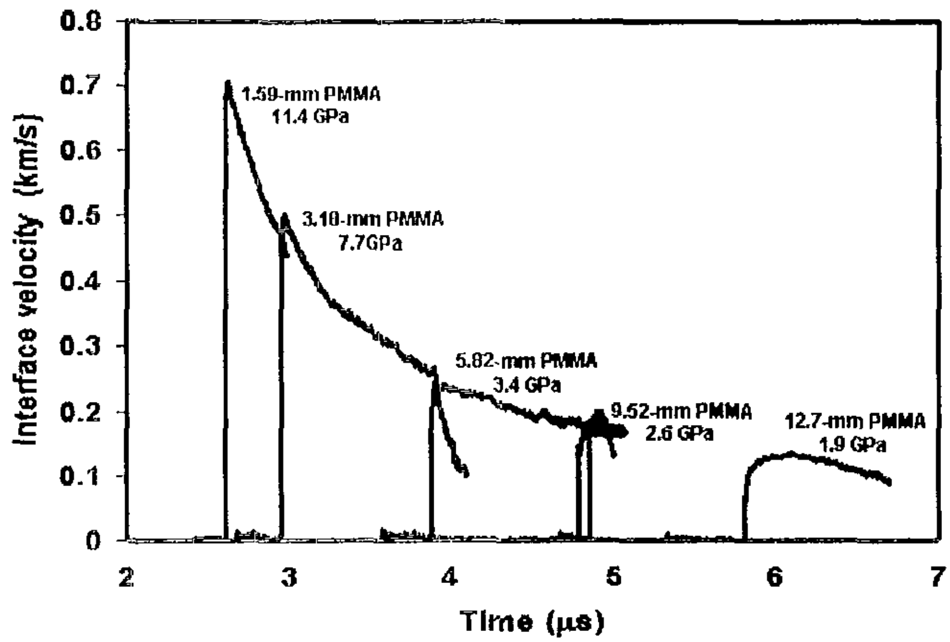

Figure 3. Velocity wave profiles measured on the axis of the small-scale test fixture.

As shown in Fig. 2, a 6.35-mm-diameter, 3-mm-thick disk of Detasheet[1], initiated by a RISI RP-2 detonator, transmitted a shock through a PMMA barrier into a LiF window. The explosive components, LiF window and PMMA barrier were confined in a partially-reusable steel fixture that contained almost all of the debris from the shot. The LiF window was 15-mm in diameter and 5 mm thick. There was a 13-μm-thick aluminum foil between the Detasheet and the LiF, from which we reflected a laser beam from a frequency-doubled, YAG laser. We could determine the velocity-time history of the interface from the Doppler shift of the reflected light, using a Fabry-Perot laser velocimeter. The front face of the window was inclined at an angle of 5^0 with respect to the rear face so that the front-surface reflection was not collected by the velocimeter optics. Figure 3 shows interface velocities measured for various thickness barriers. These interface velocities gave calculated pressures in the LiF that were appropriate to the range of shock threats that we wished to consider (fragment impact or sympathetic detonation).

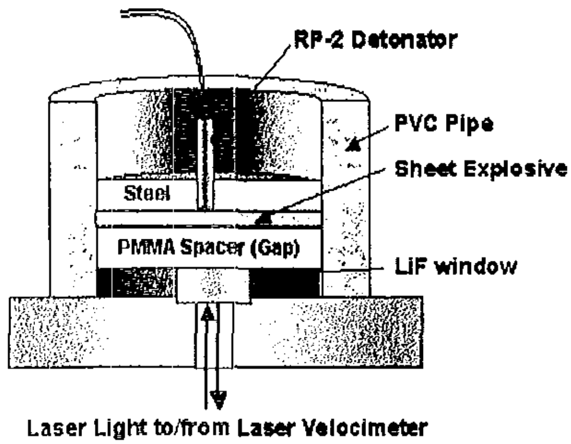

Figure 4. 100-mm Fixture configured for shock wave profile measurements.

Our next task was to measure the shock wave profiles transmitted across the PMMA gap in the 10-cm fixture shown in Fig. 1. For these measurements we reconfigured the fixture as is shown in Fig 4. Measured and calculated wave profiles for the 10-cm fixture are shown in Fig. 5. Calculations were made using the CALE 2D hydrodynamic code[2]. The pressures measured on the axis of the 10-cm fixture were slightly higher, but very similar to those determined using the small-scale fixture.

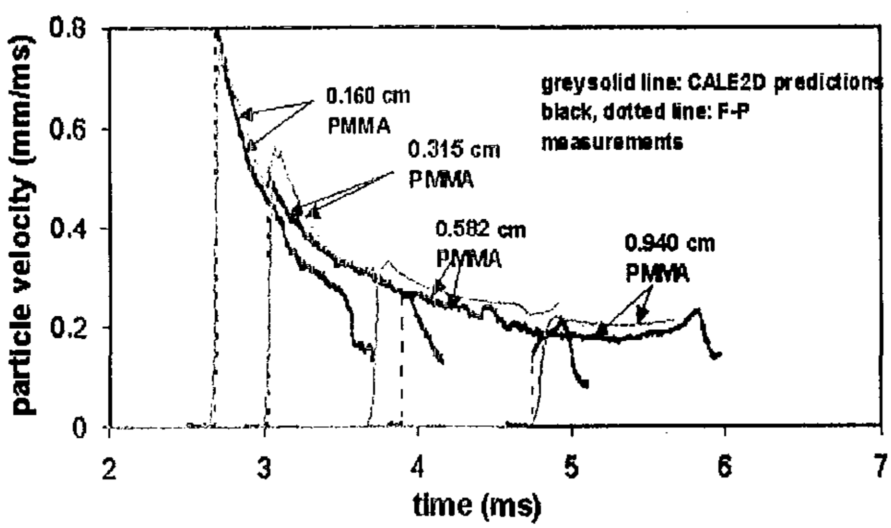

Figure 5. Velocity wave profiles measured on the axis of the larger-scale fixture, compared with CALE-2D calculations. Comparing with Fig. 3, we see that the velocity peaks measured in the larger experiment are only slightly higher and the profiles are nearly the same.

An advantage of the 10-cm-diameter fixture is that it can reproducibly shock load initiation components like detonators, leads, large boosters for insensitive munitions or even complete initiation trains. The 10-cm-diameter disk of Detasheet, has a mass of about 36 g, so the fixture is destroyed in the experiment, but is simple to build and uses low-cost materials. Detonation of the Detasheet imparts a significant velocity to the rear plate, so if the fixture is used in a firing tank, appropriate shielding must be used to shield the tank walls. If the component under test has sufficient explosive output, the fixture is configured as in Fig. 1, where a metal witness plate provides evidence of detonation or non-detonation. For small components, e.g. small detonators or slapper detonator pellets, it can be difficult to determine whether a detonation has occurred using a witness plate, so we use a configuration as in Fig. 4, where we use a laser beam to measure either the velocity of the metal case of the component, or the shock wave transmitted into a LiF window in contact with the component. One can then easily distinguish between the effect of a detonation and the shock wave from the Detasheet.

Test Results for a Hemispherical EBW Detonator

We have measured the initiation threshold for a hemispherical EBW detonator. A drawing of the detonator is shown in Fig. 6.

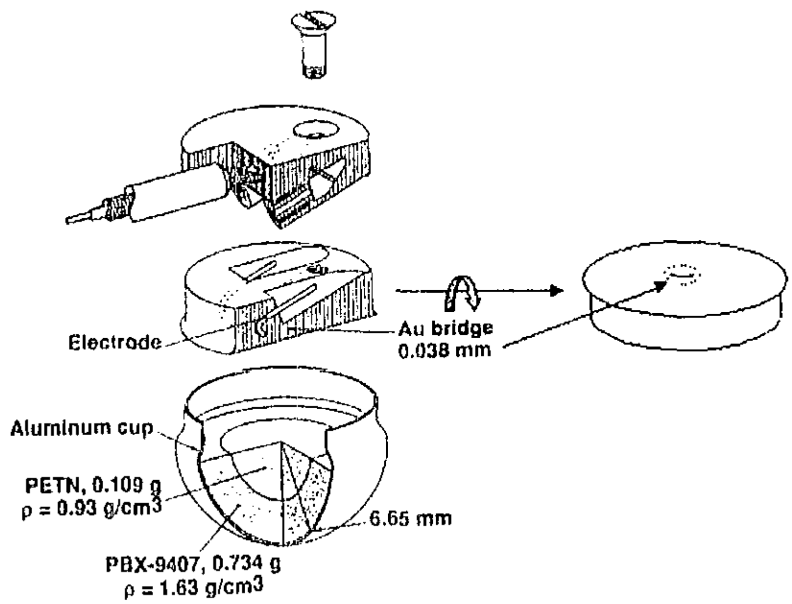

Figure 6. Drawing of a hemispherical EBW detonator containing 0.93 g of PETN and 0.734 g of PBX-9407 (94%RDX/6% Exon 461 binder).

For this study we used a 12.7-mm-thick aluminum witness plate. The criterion for detonation was a deep dent in the block and spall on the back side, opposite the test article. Figure 7 shows a photograph of a witness block after the shot. The radial spall was not due to the test article, but was produced by the shock wave from the detasheet.

The Neyer protocol[3] was used for choosing the sequence of gap thicknesses and the results are shown in Fig. 8. Threshold occurred at a gap thickness of about 6 mm at a peak pressure of about 3.5 GPa.

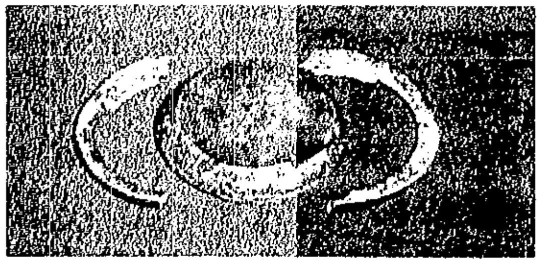

Figure 7. Aluminum witness plate used in a gap test conducted on a hemispherical EBW detonator. A dent in the witness plate indicates that the test article detonated. The circular spall around the edges is due to the shock wave from the Detasheet.

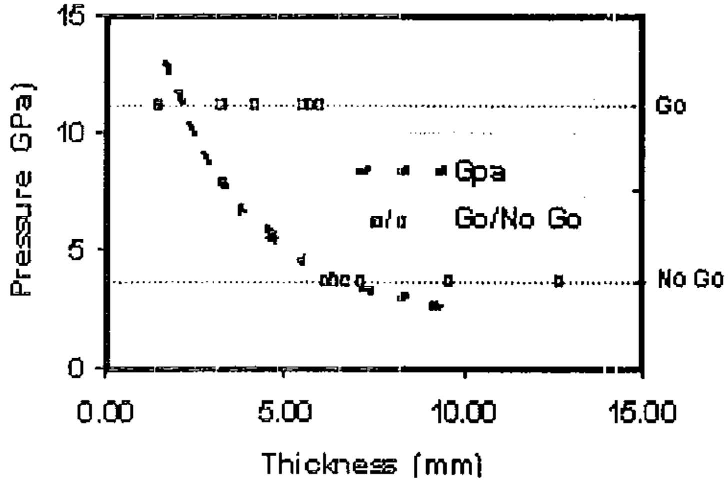

Figure ~~7~~ 8. Gap test threshold data for a hemispherical EBW detonator. Also plotted is the peak pressure curve (dotted line) with the pressure axis on the left.

Summary and Conclusions

We have developed a small-scale safety test for initiation train components. A test fixture has been designed in which a 10-cm-diameter disk of 3-mm-thick Detasheet, initiated at its center by a RISI, RP-2 detonator, produces a shock wave that is attenuated by a variable-thickness PMMA spacer (gap). The detonator, confinement plates PMMA spacer, test article and a metal witness plate are held in a low-cost, expendable fixture. We have calibrated the test by measuring the wave profiles transmitted through a range of gap thicknesses, using a Fabry-Perot laser velocimeter. Detonation of the test article is evidenced by a strong dent in the witness plate. For test articles too small to give a dent distinguishable from the deformation from the Detasheet, we use a laser beam, impinging on the test article, to determine the response. Using the new test we have determined the initiation threshold of a utility, hemispherical EBW detonator. The detonator, which contains low-density PETN and PBX-9407, initiated at and above a peak shock pressure of about 3.5 GPa.

References

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